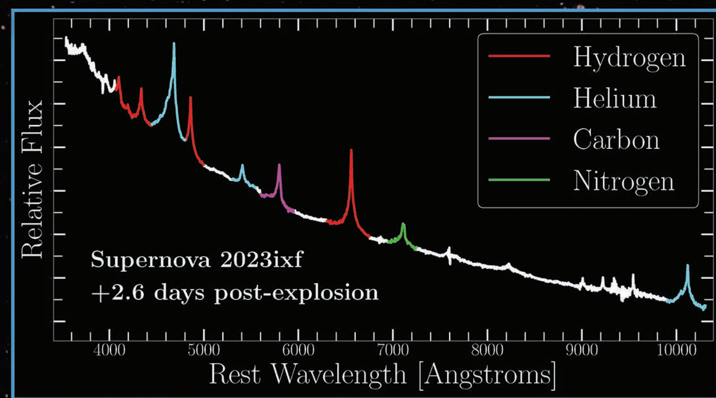
BERKELEY ASTRONOMY

UNIVERSITY OF CALIFORNIA, BERKELEY
WINTER 2023-2024



The spectrum of optical light from the supernova 2.6 days after the initial explosion, as the stellar debris is plowing through the gas around the star. The plot of light intensity versus wavelength shows peaks or emission lines from ionized elements in the circumstellar material illuminated by the supernova shockwave. These emission features—hydrogen, helium, carbon and nitrogen—are characteristic of core collapse supernovae, but fade as the supernova moves into lower density circumstellar material. Image credit: Wynn Jacobson-Galán, Ryan Chornock, Raffaella Margutti/ UC Berkeley. Image includes an artist impression of a supernova.

Astronomy in the News

CLOSEST SUPERNOVA IN A DECADE REVEALS HOW EXPLODING STARS EVOLVE

By Robert Sanders

Alex Filippenko is the kind of guy who brings a telescope to a party. True to form, at a soiree on May 18 this year, he wowed his hosts with images of star clusters and colorful galaxies — including the dramatic spiral Pinwheel Galaxy — and snapped telescopic photos of each.

Only late the next afternoon did he learn that a bright supernova had just been discovered in the Pinwheel Galaxy. Lo and behold, he'd also captured it, at 11 p.m. the night before—11 and a half hours before the explosion's discovery on May 19 by amateur astronomer Koichi Itagaki in Japan.

Filippenko, a professor of astronomy at the University of California, Berkeley, graduate student Sergiy Vasylyev and postdoctoral fellow Yi Yang threw out their planned observations at the UC's Lick Observatory on Mount Hamilton a few hours later to focus on the exploding star, which had been dubbed SN 2023ixf. They and hundreds of other astronomers were eager to observe the nearest supernova since 2014, a mere 21 million light years from Earth.

These observations were the earliest-ever measurements of polarized light from a supernova, showing more clearly the evolving shape of a stellar explosion. The polarization of light from distant sources like supernovae provides the best information on the geometry of the object emitting the light, even for events that cannot be spatially resolved.

"Some stars prior to exploding go through undulations — fitful behavior that gently ejects some of the material — so that when the supernova explodes, either the shock wave or the ultraviolet radiation causes the stuff to glow," Filippenko said. "The cool thing about the spectropolarimetry is that we get some indication of the shape and extent of the circumstellar material."

The spectropolarimetry data told a story in line with current scenarios for the final years of a red supergiant star about 10 to 20 times more massive than our sun: Energy from the explosion lit up clouds of gas that the star shed over the previous few years; the ejecta then punched through this gas, initially perpendicular to the bulk of the circumstellar

Continued on page 2

CONTENTS

material; and finally, the ejecta engulfed the surrounding gas and evolved into a rapidly expanding, but symmetric, cloud of debris.

The explosion, a Type II supernova resulting from the collapse of the iron core of a massive star, presumably left behind a dense neutron star or a black hole. Such supernovae are used as calibratable candles to measure the distances to distant galaxies and map the cosmos.

Another group of astronomers led by Ryan Chornock, a UC Berkeley adjunct associate professor of astronomy, gathered spectroscopic data using the same telescope at Lick Observatory. Graduate student Wynn Jacobson-Galán and professor Raffaella Margutti analyzed the data to reconstruct the pre- and post-explosion history of the star, and found evidence that it had shed gas for the previous three to six years before collapsing and exploding. The amount of gas shed or ejected before the explosion could have been 5% of its total mass — enough to create a dense cloud of material through which the supernova ejecta had to plow.

"I think this supernova is going to make a lot of us think in much more detail about the subtleties of the whole population of red supergiants that lose a lot of material before explosion and challenge our assumptions about mass loss," Jacobson-Galán said. "This was a perfect laboratory to understand in more detail the geometry of these explosions and the geometry of mass loss, something we already felt ignorant about."

The improved understanding of how Type II supernovae evolve could help refine their use as distance measures in the expanding universe, Vasylyev said.

The two papers describing these observations have been accepted for publication in The Astrophysical Journal Letters. Margutti and Chornock are co-authors of both papers.

ONE OF THE MOST STUDIED SUPERNOVAE TO DATE

In the more than three months since the supernova's light reached Earth, perhaps three dozen papers have been submitted or published about it, with more to come as the light from the explosion continues to arrive and the observations of a variety of telescopes are analyzed.

"In the world of Type II supernovae, it's very rare to have basically every wavelength detected, from hard X-rays to soft X-rays to ultraviolet, to optical, near-infrared, radio, millimeter. So it's really a rare and unique opportunity," said Margutti, a Berkeley professor of physics and of astronomy. "These papers are the beginning of a story, the first chapter. Now we are writing the other chapters of the story of that star."

"The big-picture question here is we want to connect how a star lives with how a star dies," Chornock said. "Given the proximity of this event, it will allow us to challenge the simplifying assumptions that we have to make in most of the other supernovae we study. We have such a wealth of detail that we're going to have to figure out how to fit it all together to understand this particular object, and then that will inform our understanding of the broader universe."

Lick Observatory's telescopes on top of Mount Hamilton near San Jose were critical to the astronomers' efforts to assemble a complete picture of the supernova. The Kast spectrograph on the Shane 120-inch telescope is able to switch quickly from a normal spectrometer to a spectropolarimeter, which allowed Vasylyev and Filippenko to obtain measurements of both the spectrum and its polarization. The group led by Jacobson-Galán, Chornock and Margutti employed both the Kast spectrograph and the photometer on the

The Pinwheel Galaxy, or Messier 101, on May 21, 2023, four days after the light from the supernova 2023ixf reached Earth. Image credit: Steven Bellavia

Nickel 40-inch telescope, with photometry (brightness measurements) also from the Pan-STARRS telescope in Hawaii through the Young Supernova Experiment collaboration.

The polarization of light emitted by an object — that is, the orientation of the electric field of the electromagnetic wave — carries information about the shape of the object. Light from a spherically symmetric cloud, for example, would be unpolarized because the electric fields symmetrically cancel. Light from an elongated object, however, would produce a nonzero polarization.

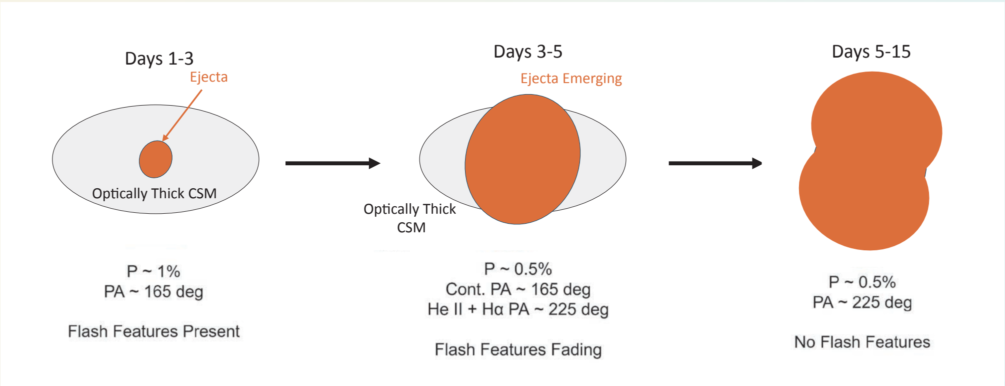
While polarimetry measurements of supernovae have been going on for more than three decades, few are close enough — and thus bright enough — for such measurements. And no other supernova has been observed as early as 1.4 days after the explosion, as with SN 2023ixf.

THE OBSERVATIONS YIELDED SOME SURPRISES

"The most exciting thing is that this supernova shows a very high continuum polarization, nearly 1%, at early times," Vasylyev said. "That sounds like a small number, but it's actually a huge deviation from spherical symmetry."

Based on the changing intensity and direction of polarization, the researchers were able to identify three distinct phases in the evolution of the exploding star. Between one and three days after the explosion, the light was dominated by emission from the circumstellar medium, perhaps a disk of material or lopsided blob of gas shed earlier by the star. This was due to ionization of the surrounding gas by ultraviolet and X-ray light from the explosion and by stellar material plowing through the gas, so-called shock ionization.

Read the full story online at:
https://news.berkeley.edu/2023/08/29/releases-20230828-6895045



Berkeley astronomers inferred these three steps in the evolution of the explosion from the changing polarimetry they observed at Lick Observatory. Before about 2.5 days after the explosion, the supernova ejecta were still enclosed within the dense, aspherical circumstellar medium (left). Then, between days 2.5 and 4.6, the aspherical supernova ejecta emerged (center), gradually expanding after day 4.6 to engulf the material (right). Image credit: Sergiy Vasylyev, Yi Yang and Alex Filippenko/UC Berkeley

JAMES WEBB SPACE TELESCOPE SEES JUPITER MOONS IN A NEW LIGHT

By Robert Sanders

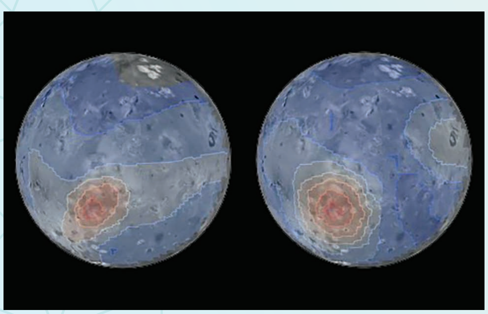
With its sensitive infrared cameras and high-resolution spectrometer, the James Webb Space Telescope (JWST) is revealing new secrets of Jupiter's Galilean satellites, in particular Ganymede, the largest moon, and Io, the most volcanically active.

In two separate publications, astronomers who are part of JWST's Early Release Science program report the first detection of hydrogen peroxide on Ganymede and sulfurous fumes on Io, both the result of Jupiter's domineering influence.

"This shows that we can do incredible science with the James Webb Space Telescope on solar system objects, even if the object is really very bright, like Jupiter, but also when you look at very faint things next to Jupiter," said Imke de Pater, professor emerita of astronomy and earth and planetary science at the University of California, Berkeley. De Pater and Thierry Fouchet from the Paris Observatory are co-principal investigators for the Early Release Science solar system observation team, one of 13 teams given early access to the telescope.

IO'S SULFUROUS ENVIRONMENT

In a paper accepted for publication in the journal JGR: Planets, a publication of the American Geophysical Union, de Pater and her colleagues report new Webb observations of Io that show several ongoing eruptions, including a brightening at a volcanic complex called Loki Patera and an exceptionally bright eruption at Kanehekili Fluctus. Because Io is the only volcanically active moon in the solar system—Jupiter's gravitational push and pull heats it up—studies like this give planetary scientists a different perspective than can be obtained by studying volcanoes on Earth.



JWST measurements obtained in November 2022 overlaid on a map of Io's surface. Thermal infrared measurements (right) show a brightening of Kanekehili Fluctus, a large and, during the observation period, very active volcanic area on Io. Spectral measurements (left) show forbidden infrared emissions from sulfur monoxide centered on the volcanic area. The coincidence confirms a theory that SO is produced in volcanic vents and, in the very thin atmosphere of Io, remain around long enough to emit the forbidden line that would normally be suppressed by collisions with other molecules in the atmosphere. Image credit: Chris Moeckel and Imke de Pater, UC Berkeley; Io map courtesy of USGS

For the first time, the researchers were able to link a volcanic eruption—at Kanehekili Fluctus—to a specific emission feature produced by so-called "forbidden" transitions of the gas sulfur monoxide (SO).

Sulfur dioxide (SO_2) is the main component of Io's atmosphere, coming from sublimation of SO_2 ice, as well as ongoing volcanic eruptions, similar to the production of SO_2 by volcanos on Earth. The volcanos also produce SO, which is much harder to detect than SO_2. In particular, the forbidden SO emission line is very weak because SO is in such low concentrations and produced for only a short time after being excited. Moreover, the observations can only be made when Io is in Jupiter's shadow, when it is easier to see the glowing SO gases. When Io is in Jupiter's shadow, the SO_2 gas in Io's atmosphere freezes out onto its surface, leaving only SO and newly emitted volcanic SO_2 gas in the atmosphere.

"These observations with Webb show for the first time that this excited SO actually did come from a volcano," de Pater said.

This piece is adjusted from original article. Read the full story online at: https://news.berkeley.edu/2023/07/27/james-webb-space-telescope-sees-jupiter-moons-in-a-new-light/

AFTER 15 YEARS, PULSAR TIMING YIELDS EVIDENCE OF COSMIC GRAVITATIONAL WAVE BACKGROUND

By Robert Sanders

The universe is humming with gravitational radiation, a very low-frequency rumble that rhythmically stretches and compresses spacetime and the matter embedded in it.

That is the conclusion of several groups of researchers from around the world who simultaneously published a slew of journal articles in June 2023 describing more than 15 years of observations of millisecond pulsars within our corner of the Milky Way galaxy. At least one group, the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) collaboration, has found compelling evidence that the precise rhythms of these pulsars are affected by the stretching and squeezing of spacetime by these long-wavelength gravitational waves.

This is key evidence for gravitational waves at very low frequencies, says Vanderbilt University's Stephen Taylor, who co-led the search and is the current chair of the collaboration. After years of work, NANOGrav is opening an entirely new window on the gravitational-wave universe.

Gravitational waves were first detected by the Laser Interferometer Gravitational-Wave Observatory (LIGO) in 2015. The short-wavelength fluctuations in spacetime were caused by the merger of smaller black holes, or occasionally neutron stars, all of them weighing in at less than a few hundred solar masses.

The question now is: Are the long-wavelength gravitational waves with periods from years to decades also produced by black holes?

In a paper published in The Astrophysical Journal Letters (ApJ Letters), University of California, Berkeley, theoretical astrophysicist Luke Zoltan Kelley and the NANOGrav team argue that the hum is likely produced by hundreds of thousands of pairs of supermassive black holes each weighing billions of times the mass of our sun that over the history of the universe have gotten close enough to one another to merge. The team produced simulations of supermassive black hole binary populations containing billions of sources and compared the predicted gravitational wave signatures with NANOGravs most recent observations.

The black holes' orbital dance prior to merging vibrates spacetime analogous to the way waltzing dancers rhythmically vibrate a dance floor. Such mergers over the 13.8-billion-year age of the universe produced gravitational waves that today overlap, like the ripples from a handful of pebbles tossed into a pond, to produce the background hum. Because the wavelengths of these gravitational waves are measured in light years, detecting them required a galaxy-sized array of 'antennas' formed from a collection of millisecond pulsars.

Read the full story online at: https://news.berkeley.edu/2023/06/28/after-15-years-pulsar-timing-yields-evidence-of-cosmic-gravitational-wave-background/

News and Noteworthy

Professor Emeritus, Gibor Basri was nominated to the American Astronomical Society (AAS). Members are recognized for original research and publications, innovative contributions to astronomical techniques or instrumentation, significant contributions to education and public outreach, and noteworthy service to astronomy and to the Society itself.

Professor Basri was nominated for sustained contributions in the areas of accretion onto T Tauri stars, studies of stellar rotation and activity, direct detection of stellar magnetic fields, discovery and pioneering work on brown dwarfs and lithium dating, and service to the AAS as the founding chair of the Committee on the Status of Minorities in Astronomy and co-chair of the 2018 Task Force on Diversity in Graduate Education.

DRESSING TO HEAD PLANNING TEAM FOR HABITABLE WORLDS OBSERVATORY, A NEW NASA FLAGSHIP

By Avi Rosenzweig

Courtney Dressing, Associate Professor of Astronomy, has had her eye on exoplanets for a long time. In 2005, when astronomers were able for the first time to observe infrared light directly emanating from an exoplanet,[1] Dressing was doing a summer high-school internship at NASA's Goddard Space Flight Center in Maryland with Tilak Hewagama from Drake Deming's lab as her mentor. The group was looking at the atmospheric compositions of Mars, Saturn, and Titan, at a time when. The composition of exoplanet atmospheres was all speculative. Fast forward to today: there are over five thousand confirmed exoplanets in the Milky Way, and Professor Dressing is a leader in guiding NASA's new push to learn which of them is compatible with life.

The Habitable Worlds Observatory (HWO) flagship NASA mission resulted from the 2020 Astrophysics Decadal Survey.[2] The HWO will pursue a range of astrophysics goals, including searching for and characterizing potentially habitable planets beyond our solar system. It will be the first NASA mission designed specifically to look for signs of life on potentially habitable exoplanets, all while contributing to our broader understanding of the cosmos. Professor Dressing has been selected as Co-Chair of the HWO Science, Technology, Architecture Review Team for the initial mission planning.

"Just as thousands of people were involved in the planning for the James Webb Space Telescope, a mission like HWO will require participation from scientists and engineers around the world. Early-career researchers are particularly encouraged to get involved because they will become the leaders and users of future flagship astrophysics missions," says Dressing. The planning teams convened their first meetings recently, and Dressing was delighted to see so much engagement from community members who called in to the public sessions on Webex and joined the community Slack workspace. "We left the meeting with a clear sense of our next steps: spinning up working groups to focus on science cases and engineering topics, encouraging community members to join working groups, preparing to discuss HWO at the upcoming American Astronomical Society conference in January, and building tools to model the types of observations that could be obtained with HWO."

In her Introduction to Astrophysics (7A) class this semester, Professor Dressing is including the collection and analysis of exoplanet data as an integral part of the curriculum. The science fiction of her youth is becoming the fundamental reality of her students. "Some day in the future, after a mission has detected potentially habitable planets orbiting nearby stars, I hope to picnic with my colleagues and discuss whether anyone on those planets might be waving back at us."

[1] *Exoplanet exploration site can be reached here: https://exoplanets.nasa.gov/alien-worlds/historic-timeline/#first-light-from-an-exoplanet-observed*

[2] *Read the full survey report here: https://nap.nationalacademies.org/catalog/26141/pathways-to-discovery-in-astronomy-and-astrophysics-for-the-2020s*

A Dean in Motion: Dean Kahn Tours Chilean Facilities Vital to UC Berkeley Astronomy

By Alexander Michael Rony

The group climbed the stairs at the Vera C. Rubin Observatory and took in the sight they had traveled so far to see: the multistory frame that will soon house the largest digital camera ever constructed.

For Steven Kahn, Dean of the Division of Mathematical and Physical Sciences and Professor of Physics and Astronomy, the trip to Chile was both a homecoming and a validation of years of meticulous planning. Kahn was the observatory's former director before he joined UC Berkeley in 2022, returning to the university where he earned his Ph.D. and taught physics and astronomy.

"It was good for me to make personal contact once again with our team in Chile," said Kahn. "Chile has become the most important world center for ground-based astronomy in recent years. It is a very exciting place to visit."

In October, Kahn toured several facilities as an extension of Berkeley's fruitful partnerships in the region. Four years had passed since Kahn last ascended Cerro Pachón, the mountain that hosts the Rubin Observatory. As dean, Kahn continued to follow the project closely — especially the progress on the observatory's superlative camera.

Weighing in at over 6,700 pounds, the 3,200-megapixel camera will take images so detailed that it would take the combined resolution of 1,500 high-definition televisions to display a single image. Even the camera's sensors are advanced, requiring a constant temperature of approximately -148°F to prevent defective pixels.

"Every element of it was beyond the state of the art," said Kahn. "It's fundamentally different in architecture than all other astronomical cameras."

When the Rubin Observatory is up and running in 2025, researchers will have access to a dataset that is ten times as large as any other astronomical survey. The observatory

Steve Kahn at the Vera Rubin Observatory, images by Ted Michon

expects to discover about 20 billion galaxies and a similar number of stars. UC Berkeley's astronomers are particularly eager for the observatory's assistance in the expanding area of multi-messenger astrophysics, the coordinated observation and interpretation of different signals produced by cosmic phenomena.

In 2017, astronomers observed the GW170817 neutron star merger, an event that UC Berkeley Professor Raffaella Margutti said "changed astrophysics forever." For the first time, scientists detected the collision of two neutron stars through the emission of gravitational waves—ripples in space-time predicted in Albert Einstein's theory of general relativity. Professor Margutti is planning a workshop to develop scientific consensus on how to use the Rubin Observatory to hunt for these newly confirmed traits.

"As of now, we only have one celestial object for which we have been able to find gravitational waves and light," said Margutti. "Gravitational wave interferometers are detecting objects that are too far, and hence too faint, for current telescopes. With its exceptional combination of large field of view and exquisite sensitivity, the Rubin Observatory will be the premiere facility in the southern skies for the search of electromagnetic counterparts of gravitational waves."

Two days later, Kahn assessed construction progress at the Simons Observatory. It was Kahn's first time at the Simons Observatory, but he has advised the observatory for years. UC Berkeley is heavily invested in the facility; Adrian Lee, a professor of physics, is one of the observatory's lead investigators and sits on its executive board.

As the facility sits at an elevation of nearly 17,000 feet, Kahn and the other oxygen-assisted visitors needed to depart after a few hours. Kahn returned to his hotel. The sky darkened; the stars shone. Telescopes captured the night sky and transmitted their data to researchers around the world.

Somewhere in Berkeley, an astronomer pored over the results.

Message from the Chair

JESSICA LU REVEALS THE INCREDIBLE EXPERIENCES UC BERKELEY GIVES ITS ASTRONOMERS

By Alexander Michael Rony

Astronomy students who grew up building telescopes for backyard stargazing sessions could hardly find a better instructor than Jessica Lu. An associate professor in the Department of Astronomy, Lu studies black holes and helps design adaptive optics that sharpen images taken with major telescopes like the ones at the Keck Observatory in Hawai'i.

This year, Lu began her first stint as astronomy chair, a role that she accepted with surprise.

"I would much rather be sitting at my computer making discoveries about the universe and working with my students all day long. But the former chair, Professor Josh Bloom, really showed why a good department chair is valuable and how important it is to have a leader to steer the ship in times of crisis. I care about the department and want it to be all it can be. If that means stepping up to serve as department chair, then that is something I want to do."

True to her field, Lu radiates excitement when talking about space, particularly her specialty: black holes. She is currently exploring new avenues for research thanks to advances in data science, precision technologies for manipulating light, and low-cost space access. Lu discussed the future of her department in an interview with UC Berkeley writer Alexander Rony.

What is unique about UC Berkeley's Department of Astronomy?

The astronomy department is a fantastic place to work. One thing that sets Berkeley apart from other universities is this ability to be both a large, public state school and have an incredible student body that's diverse and brings all their amazing backgrounds to bear on scientific research. I also love the techy mindset at UC Berkeley. We absorb it from the Bay Area—or perhaps help create it.

When you grow up in a city now, you can't look up and see the stars every night. It's amazing that, as astronomy professors and researchers, our ability to communicate what we see in the universe inspires all these new students.

UC Berkeley is in a unique position where we're not only making today's high-impact discoveries about the universe but also training the next generation of diverse scientists to take their place in the world as astronomers, educators, policymakers, and engineers. When they leave Berkeley, they'll depart with their scientific skillset, curiosity, and passion for the universe, and we hope that they carry that on into their next endeavors—wherever that might be.

What is especially promising about the department's current research projects?

The amount of data that we have access to in the field of astronomy has exploded. The scales are just immense—we're talking about terabytes of data every night that's taken with just one telescope. We have to sift through these incredible troves of data to find the cream of the crop. Our ability to take movies of the universe is completely new in the last decade, as is our ability to probe the universe with both light and these ripples in spacetime called gravitational waves.

Right now, there's an intense focus on black hole studies. Professors Raffaella Margutti, Chung-Pei Ma, Dan Kasen, Wenbin Lu, Alex Filippenko, Josh Bloom and myself: there's a huge number of faculty—plus all of the students and postdocs in our groups—who are working on black holes from different angles, whether that's through theory or observation with the full array of the electromagnetic spectrum.

Professors Courtney Dressing and Eugene Chiang and their students are working to understand where exoplanets exist in the universe and whether they can harbor life. Professor Dressing was just selected to co-chair a large international team of scientists planning and designing the next NASA flagship mission, Habitable Worlds Observatory. This mission will enable us to image Earth-like planets around nearby stars in the next 20-30 years.

We have amazing groups in cosmology, stars, and planets. UC Berkeley is also renowned for its time-domain astronomy. For instance, our newest Miller Postdoctoral Fellow, Dr. Yuhan Yao, is studying how stars are ripped apart by supermassive black holes like the one that sits at the center of our galaxy. After these stars are ripped apart, the black hole gobbles up its mass and launches a violent jet so powerful and high-energy it can escape the entire galaxy. It's pretty fun stuff!

What priorities are important to the department and to you, as chair, over the next year?

My most important priority is to continue to grow the department. We have an increasing number of undergraduate students who want to major in astronomy and astrophysics, and we would like to provide research opportunities for all of them. Each of our faculty are already working with about 10 undergraduates on individual research projects, and we're still having to turn students away. For undergraduates, working at the forefront of research is a transformative experience. They'll take that with them after they leave UC Berkeley.

We'd like to hire the best faculty and provide them with startup funding to employ the brightest and sharpest students, build the most innovative instruments, and have access to the computational power they need. We would also love financial support to help our students live in the Bay Area.

What are the different telescopes available to faculty and students thanks to their association with Berkeley?

UC Berkeley students, postdocs, and faculty have access to an incredible amount of resources. The combined resources of UC Berkeley, Lawrence Berkeley Lab, Space Sciences Lab, and Lawrence Livermore Lab give our students amazing opportunities to work with some of the best minds in the world.

Our students get to use two of the biggest telescopes in the world at the Keck Observatory on Mauna Kea in Hawai'i. They get to drive the telescope themselves. By the end of the night, you are exhausted, but you're in command.

That is an incredible experience. It's one that is rare now. Telescope time is getting harder to come by. It's more competitive. If you want to use a space telescope, we use the Hubble Space Telescope and the James Webb Telescope—we even build our own. Right up the hill at Space Sciences Lab, we have students developing the COSI project, which will be a gamma-ray telescope launched into space. Our students are going to build the instruments that help discover all kinds of interesting phenomena in the universe that produce gamma rays.

You've sold me. Now, I want to go back to college. What experiences do you find particularly rewarding as a professor?

I really enjoy working with students. I love to watch them grow as scientists, as researchers, and as people. I especially like being able to give opportunities to students from underrepresented backgrounds who might not have had such opportunities before Berkeley. I grew up in a fairly financially challenged family. I was a ballerina and went to a public performing arts high school. If you had looked at me, you wouldn't have thought "scientist" from my background. Somebody took a chance on me. They gave me a shot to go to MIT. They gave me a shot to do research very early on as an undergraduate. One of my favorite parts about being a professor is being able to turn around and give those same opportunities to new students coming in.

Continued on page 7

Research Fellows and Postdocs

Dr. Nayana A.J. is a postdoctoral scholar who joined UC Berkeley in September 2023. Her research focuses on the study of various explosive transients including supernovae, gamma-ray bursts, cataclysmic variables, and fast blue optical transients. She uses multi-wavelength follow-up observations to understand the energetics and environments of these events. She is particularly interested in looking at the radio emission that arises due to the interaction of fast-moving outflows from these transients with the surrounding medium. She models the spectral and temporal evolution of the radio emission to understand the shock properties and progenitor scenario of these cosmic explosions. Nayana is currently working on modeling the multi-wavelength emission from one of the nearest supernovae of the decade to understand its progenitor system and complex circumstellar medium.

Dr. Sanjana Curtis is an NSF fellow, who joined UC Berkeley in September 2023. Her research lies at the intersection of nuclear astrophysics and multi-messenger astrophysics, and connects high physical-fidelity numerical simulations of core-collapse supernovae and compact object mergers to observables such as abundances, light curves, and spectra. Currently, she is working on the multi-dimensional modeling of kilonova transients. She is also predicting nucleosynthesis yields of core-collapse supernovae and examining how they correlate with the properties of their progenitor massive stars.

Dr. Macy Huston is a postdoctoral scholar. They arrived in Fall 2023 and are working in the Moving Universe Lab on the use of gravitational microlensing to study stellar mass black holes in the Milky Way, both through observations and simulations. Macy is working on reanalysis of several long-timescale microlensing events with improved software for processing Keck telescope adaptive optics imaging. They are also working on software development for finding candidate black hole microlensing events, microlensing model fitting, and microlensing survey simulations. As the chair of the La Silla Schmidt Southern Survey Galactic Science Working Group, they are coordinating a survey of the Galactic bulge and plane to search for microlensing events and other Galactic transients.

Dr. Calvin Leung is a NHFP Einstein Fellow at UC Berkeley in the Department of Astronomy. He completed his PhD in 2023 at MIT and is a leader in the CHIME/FRB Outriggers Project, which aims to VLBI-localize hundreds of fast radio bursts (FRBs) every year. This will uncover the mystery of FRBs and will open up their use as a new tracer of baryonic large-scale structure. He is a Bay Area native and in his spare time he loves running and playing the cello.

Dr. Rixin Li is a 51 Pegasi b Fellow, who just joined UC Berkeley in the Fall of 2023. His research uses computational simulations to understand the evolution of protoplanetary disks, the formation of planets therein, and the evolution of black holes embedded in active galactic nucleus disks. Based on these calculations, he makes observable predictions to test the underlying theories. Currently, he is examining how planets can form early and rapidly in young protoplanetary disks and how part of the Kuiper Belt might form late in the solar nebula's lifetime, both of which will offer new insights into the interpretations of recent and forthcoming observations by ALMA & JWST. He is also examining how embedded binary black holes can produce mergers detected in gravitational waves by LIGO/Virgo.

Dr. Emily Liepold is a Heising-Simons foundation postdoctoral scholar, who just completed her Ph.D. here at Berkeley. Her work orbits around searches for the largest supermassive black holes in our neighborhood using stellar dynamical orbit-based methods. As part of this effort, she works to extend and develop computational techniques for modeling the stellar orbits of the largest nearby elliptical galaxies where these black holes tend to reside. Through this work she explores the relationships between galaxies' shapes, their constituent components, and their underlying stellar orbital structures.

Dr. Mark Ruzindana received a PhD in Electrical and Computer engineering with an emphasis in Signal Processing from Brigham Young University, where he worked in the radio astronomy systems (RAS) group. Mark primarily worked on the software for the digital back ends of the heterogeneous computing platforms used for radio astronomy (the focal L-band array for the Green Bank telescope) and wireless communications (a phased array receiver system capable of real-time RFI mitigation).

His current projects include the Hat Creek Radio Observatory national radio dynamic zone (HCRO-NRDZ) project, the Breakthrough Listen User supplied Equipment (BLUSE) project at MeerKAT, and the Commensal Open-Source Multimode Interferometer Cluster (COSMIC) project at the VLA. BLUSE and COSMIC involve the search for extraterrestrial intelligence (SETI) institute.

Dr. Ramanakumar Sankar is a postdoctoral scholar working on studying giant planet atmospheres, mainly Jupiter and Saturn. Specifically, he is using numerical fluid dynamical models to understand the processes that drive convection and storm formation, in an effort to constrain the structure of the atmosphere below the cloud layers, and determine heavy-element abundances on these planets, which is a key unknown in the studies of solar system giant planet atmospheres.

Dr. Yuhan Yao is a Miller postdoctoral fellow. She obtained her Ph.D. in June 2023 from Caltech, and received her B.S. in Astronomy from Peking University in 2018. With a broad interest in time domain astronomy and high energy astrophysics, she uses wide-field sky surveys and targeted multi-wavelength observations to study the physics of energetic transients, such as the disruption of stars by massive black holes and the explosions of stars. She is currently working on detailed X-ray spectral modeling of a tidal disruption event to study super-Eddington accretion in the system.

Undergraduate Affairs Highlights

Cal Day 2023

Cal Day is an opportunity for newly admitted students and their families to experience all that UC Berkeley has to offer. The astronomy department faculty, students, and staff hosted events throughout the day for intended astrophysics majors. Soon after Cal Day, students made one of their most important decisions: which college to attend. At Launch Day in August, our outreach paid off when we welcomed 115 first-years and 20 transfer students intending to major in astrophysics at Berkeley!

Astrophysics majors and staff tabling at Cal Day 2023

Astronomy Professor, Aaron Parsons, gives a tour of the Radio Astronomy Lab (RAL) to incoming students during Launch Day '23.

Welcome to our Newest Group of Graduate Students!

Olivia Aspegren (*Physics, Yale University*) previously worked with Prof. Howard Smith, studying cosmic ray ionization in the interstellar medium of luminous infrared galaxies, as well as with Prof. Meg Urry, using X-ray observations to characterize heavily obscured active galactic nuclei. She now conducts research with Prof. Liang Dai on the emission from turbulent mixing layers in the interstellar medium.

Savannah Cary graduated from Wellesley College (*Astrophysics and East Asian Studies*) where she mostly worked under the CHIME (The Canadian Hydrogen Intensity Mapping Experiment) collaboration to study Fast Radio Bursts (FRBs). Currently she is wrapping up her research on compact binary mergers in open clusters after spending a year at the University of Tokyo. Now at Berkeley, she is starting work with Wenbin Lu and Calvin Leung on transients such as FRBs and pulsars. Outside of work, she likes to run, read, and play ultimate frisbee!

Katie Sharpe's (*Astrophysics+Physics, Harvard College*) past research probed questions in the stellar evolution of massive black hole binary progenitors, the Milky Way's stellar halo, and galaxy clustering in the high redshift universe under Professors Selma de Mink, Charlie Conroy, and Daniel Eisenstein, respectively. She's looking forward to working with Prof. Dan Weisz to explore the evolution of isolated dwarf galaxies using JWST spectroscopy.

Undergraduate Spotlight:
Rav Kaur, Graduating Senior, Spring 2024

What is your research focus at UC Berkeley?
Gravitational waves and their applications in multi-messenger astrophysics. Previously, I have worked on a project with Dr. Palmese (now at CMU) in Prof. Perlmutter's group, where I derived a more precise value of the Hubble Constant based on gravitational wave data from the GW170817 binary neutron star merger, the latest electromagnetic data from the merger, and the peculiar velocity of the host galaxy of the merger. After this project, I shortly worked on X-ray binaries at Harvard in the summer, before coming back to work on my honors thesis with Prof. Margutti and Prof. Palmese. Currently, in my thesis, I am working on simulating afterglows attached to gravitational wave simulations to best predict the probability of detecting an afterglow in conjunction with a gravitational wave event in the next observing run (O5) for LIGO-Virgo-KAGRA. This will help us know which telescopes to propose and use that will be optimal for detecting a counterpart to a gravitational wave event detection.

What has been the most rewarding thing you have done as an undergrad in the Department of Astronomy?
Definitely managing and helping run the Physics and Astronomy Division of the Undergraduate Lab at Berkeley (ULAB). As a freshman coming into Berkeley, I had no research experience, and joined ULAB so I could feel more prepared to apply to research positions. My ULAB project ended up directly leading to the research that I have done throughout undergrad, and it had a huge impact on me, so I came back to help run the program. As one of the directors, I directly get to help traditionally underrepresented students in academia like myself become more confident and get familiar with research so they can go on to do work under faculty PIs. Getting to talk to these students once they have gone on to get research after helps me know that I get to make a difference for a lot of them, and help them build confidence in research and coding, which is absolutely the most fulfilling thing I have done in undergrad here.

What are your plans after graduation?
I plan to go to grad school to further study astrophysics. I hope to continue my work in gravitational wave physics, and to specialize in multi-messenger astrophysics, while perhaps continuing the work that I am doing currently in my honors thesis. I also want to continue pursuing music on the side during grad school!

What advice would you give future Astrophysics majors?
Get involved in the astronomy community! I have made some amazing friends and gotten some amazing opportunities simply by joining clubs like UAS, attending astro colloquia, and socializing with my fellow majors. The major is what you make of it, and doing problem sets and working on research is much more fun when you have friends to puzzle it out with on the 6th floor. I've gotten amazing research opportunities by attending research fairs and talking to post-docs and faculty in the department during colloquia. Despite the different backgrounds that students come from and the different challenges they face, everyone can find a place to fit in the astro community here. The best things I've experienced in my time at Berkeley have come out of being deeply involved in the department, and I think getting involved is the best thing for any new majors to do!

Message from the Chair, Continued from page 5

I also really enjoy giving talks to my colleagues and the public, and I love watching students give their first talks. Research can often be tedious. It takes a long time to work through the challenges, but it makes everything worth it when you finally reach the point where you have a finding you can put into a talk and tell the story of that discovery.

One of the amazing things about UC Berkeley is that our alumni love to stay connected to the department. Right now, I am working with an alum who is a fellow at the National Institutes of Health towards the end of his career, and yet he wants to come back and take classes at UC Berkeley in astronomy. We have people who have worked in our department for short periods as researchers, undergraduates, or graduate students, and decades later, they want to stay engaged. They want to hear about our new discoveries, meet the students, share their experiences, and revitalize their own passions for astronomy.

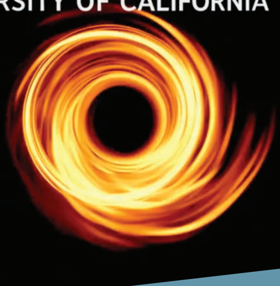
It's thanks to their generous support that we are able to hire some of the best and brightest minds, attract graduate students, grow the number of undergraduates in our major, and send our students and scholars to conferences and telescopes worldwide. I appreciate all the support at UC Berkeley for astronomical discovery and for training the next generation of scientists and educators.

To support the Department of Astronomy, visit https://give.berkeley.edu/fund/FN7219000

This interview has been edited for length and clarity.

UNIVERSITY OF
CALIFORNIA, BERKELEY
DEPARTMENT OF ASTRONOMY
501 CAMPBELL HALL #3411
BERKELEY, CA 94720-3411

Berkeley
UNIVERSITY OF CALIFORNIA



Newsletter Credits:
Guest writers: Alexander Michael Rony and Avi Rosenzweig
Astronomy department members: Jessica Lu, William Boyd, Brianna Franklin, Brandye Johnson, Maria Kies, Yasasha Ridel, and Dirk Wright
Design:
Lisa Krieshok

Supporting Astronomy

Berkeley Astronomy, home to world-renowned scientists and researchers, is universally regarded as one of the top astronomy departments in the world. Our award-winning faculty and outstanding students are engaged in some of the most fascinating research today, from studying the relationship between planets and moons in our solar system, to discovering new planets, galaxies, and black holes, to creating a road map for exploring the structure of the Universe. We invite you, our philanthropic partners, to explore the ways you can have a meaningful impact on our mission of excellence through high-quality instruction, cutting-edge experimentation, and bringing undergraduate and graduate students along in research endeavors, by supporting any of the following funds:

The Friends of Astronomy Fund directly supports all facets of the department's operations from research to instruction, recruitment of top faculty and staff, to the day-to-day technology and supply needs in the classrooms and teaching labs.

The Graduate Student Support Fund in Astronomy assists efforts to cover the necessary resources for graduate students. One of the top priorities for the Astronomy Department, and the Division of Mathematical and Physical Sciences, is advancing our recruitment efforts to attract the best and most promising graduate students. Help us strengthen the critical financial support that enables young scientists to select Berkeley for their studies.

The Student Observatory Fund assists with the maintenance of the latest instrumentation and teaching observatories managed by the Astronomy Department. The fund also provides support for the department's upper-division undergraduate laboratory course, the capstone experience for all astronomy majors.

Join us in making an impact!

Many employers will match your gifts to UC Berkeley. To discuss matching or other opportunities to support Astronomy at Berkeley, contact Ryan Guasco, Associate Development Director (rguasco@berkeley.edu, or via phone at 510-599-8698).

Or visit our website: https://astro.berkeley.edu/friends-fans/make-a-gift/

2023 Commencement Information

The Department of Astronomy Spring 2023 Commencement honored the class of 2023 to celebrate their accomplishments.

DEGREES CONFERRED 2023:
45 Astrophysics BAs
6 Astrophysics MAs
4 Astrophysics PhDs

PRIZES & AWARDS:

Department Citation
Ningyuan Xu

Dorothea Klumpke Roberts Prize
Fira Fatmasiefa

Mary Elizabeth Uhl Prize
Casey Lam
Emily Liepold

Daniel Edward Wark Award
Rav Kaur

Robert J. Trumpler Award
Chris Moeckel
Kishore Patra

Outstanding Graduate Student Instructor Awards
Natasha Abrams
Kenneth Lin
Sam Paplanus (UG)
Raphael Baer-Way (UG)

2024 Department of Astronomy Commencement will be held on Monday, May 13th at the Hertz Hall from 9 a.m. to 12 p.m.

GO BEARS!
Thank you for your supporting the future of Berkeley Astronomy!